Student Edition

California Education and the Environment Initiative

10

World History
History-Social
Science Standards
10.3.1. and 10.3.5.

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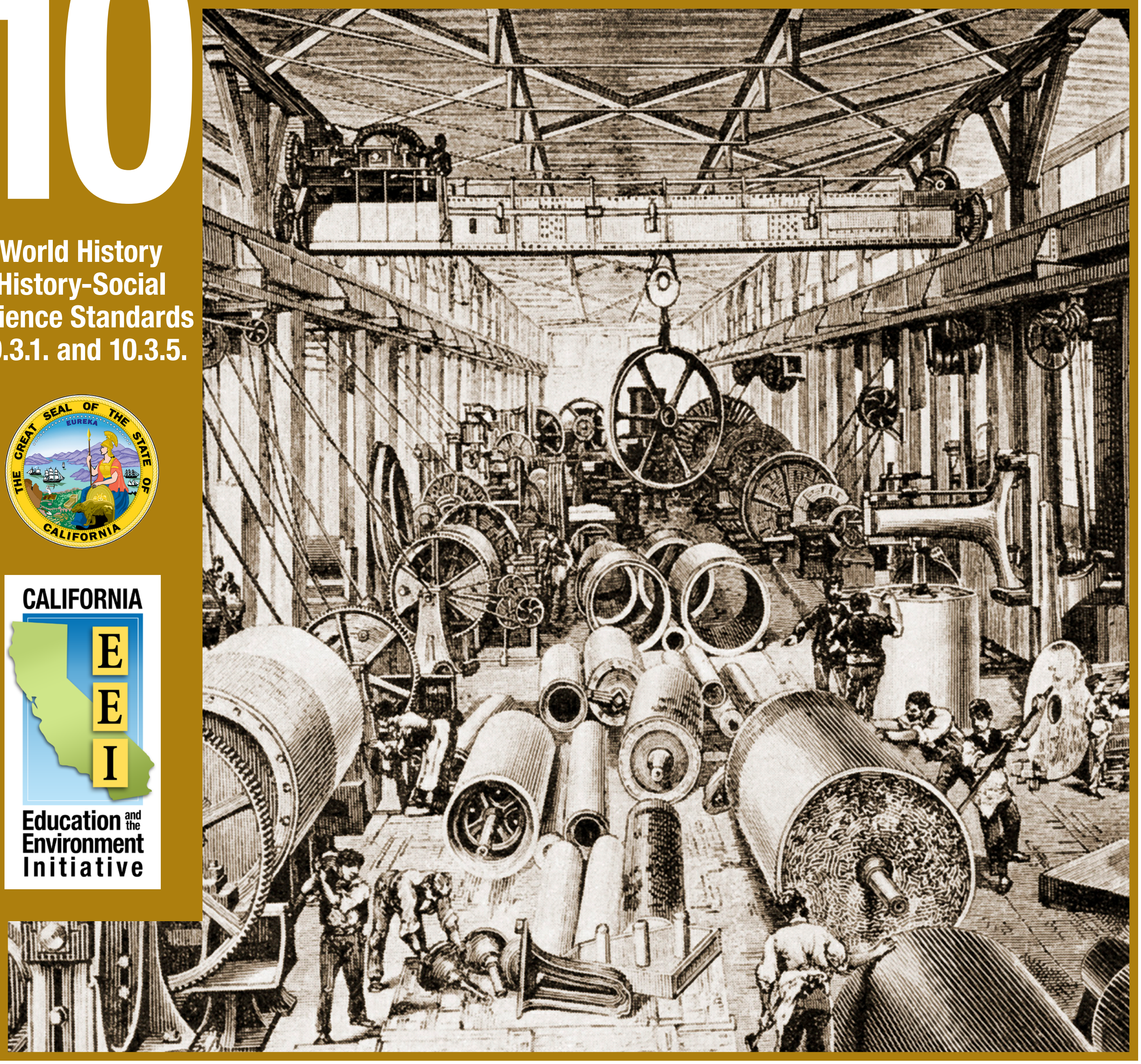

Britain Solves a Problem and Creates the Industrial Revolution

California Education and the Environment Initiative
Approved by the California State Board of Education, 2010

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California Environmental Protection Agency
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Office of the Secretary of Education
California State Board of Education
California Department of Education
California Integrated Waste Management Board

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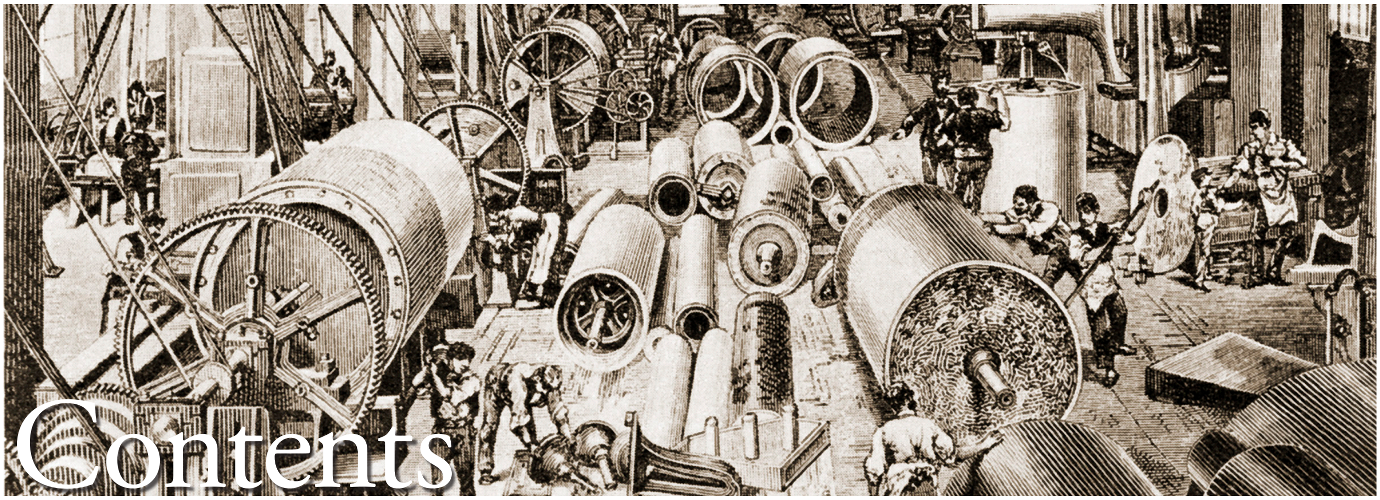

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New Challenges, New Opportunities, New Technology

Since the middle of the last century, electronic devices have transformed the way we work and live. Not too long ago, producing type for a newspaper, book, or magazine required a large machine that cast each line in metal. Highly skilled workers bound hundreds of metal lines together. They placed these lines, along with metal copies of photographs, into a metal frame. Other workers used the type in these frames to transfer ink to paper. Then trucks delivered the printed material to people to read.

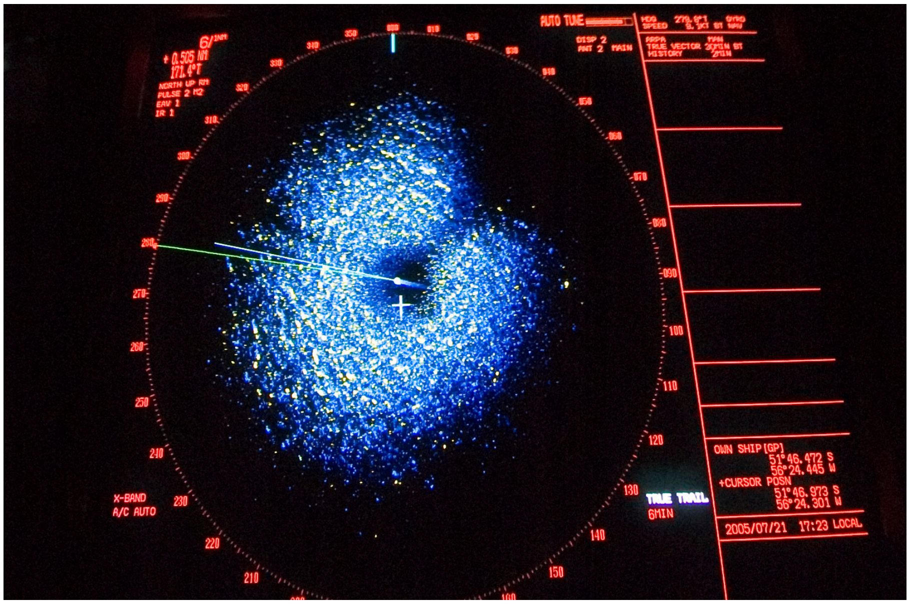
Now most of us have the skills to write our thoughts on computers, where the words are mere flickers of light. We add color photographs that also exist only as electronic signals. We then write blogs or e-mails for anyone with a computer to read instantly.

Until 130 years ago, the only way to hear music was to listen to people performing it live. Fifty years ago, people could listen to music at home on a bulky radio or television or on a delicate record player that skipped if anyone jolted the machine. Now we listen to music wherever we go on a small device that fits in a pocket and carries thousands of songs.

Changes From a Chip

Key to the electronic devices that have changed our world

Silicon Valley, San Jose, California



Radar technology

is the microchip. Scientists, entrepreneurs (people who start new businesses), and workers in Silicon Valley in northern California are among the world's leaders in developing microchips. Have you ever wondered why people call it Silicon Valley? Silicon is the main ingredient of microchips. Silicon is an element, like hydrogen, oxygen, and carbon. In fact, silicon is the second most common element on Earth. Sand is mostly silicon. Compounds containing silicon are present in many rocks and most soil. Even plants and animals contain silicon compounds.

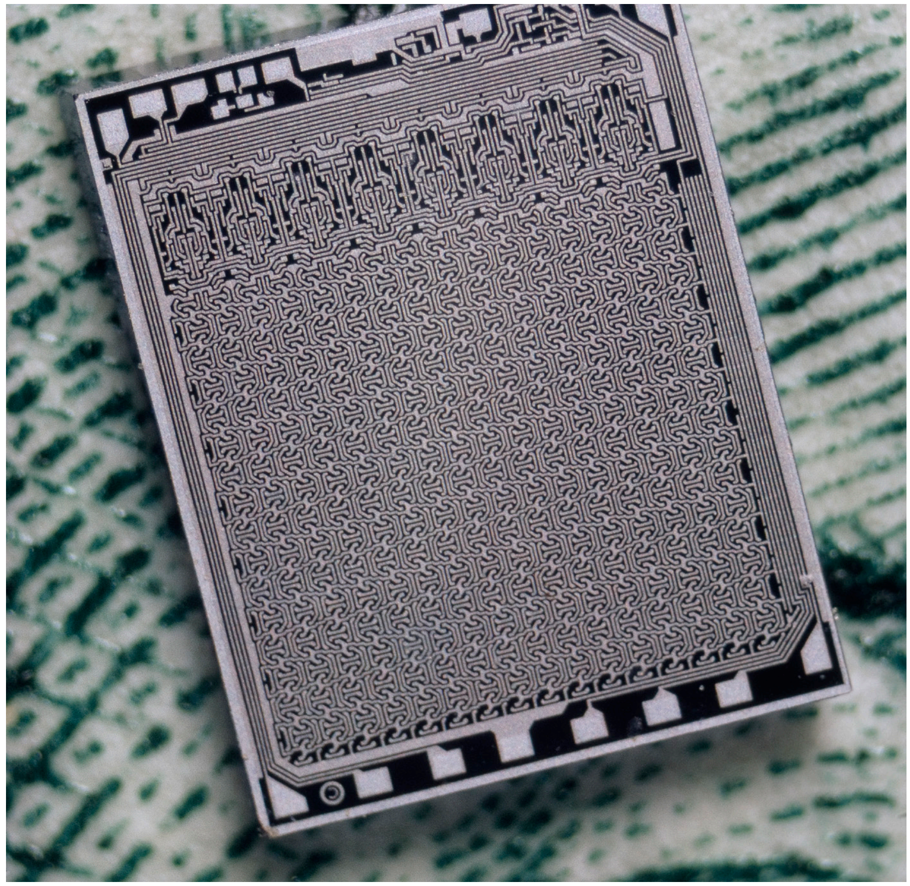
Why do we use silicon to make microchips? Silicon is a semiconductor. That means silicon sometimes conducts electricity and sometimes does not. Electronic devices produce words on a computer screen or music on a digital music player by managing tiny electrical currents. Scientists discovered that silicon is one of the best materials for containing those tiny electrical currents. Of course, silicon is not the only ingredient required to make a microchip. Microchips contain smaller amounts of elements, like copper, aluminum, and gold. The process of manufacturing chips also requires lots of energy and water.

The Innovation

Electronics innovation in Silicon Valley began in the 1930s. Engineering professors and students at Stanford University in Palo Alto took an interest in radio. Radio was a new technology. It had quickly become very popular for listening to news, music, and other entertainment. In response to the outbreak of World War II, in the early 1940s the U.S. government hired scientists around Palo Alto and elsewhere to develop military technologies. One example is radar. Radar uses electronic signals to locate ships and airplanes.

Some of this research involved semiconductors. In 1947, William Shockley and two other scientists used semiconductor technology to invent the transistor. This device can increase electrical signals or switch electrical currents off and on. The scientists worked at Bell Laboratories in New Jersey at the time. A few years later, Shockley returned to California, where he had grown up. He became director of the Shockley Semiconductor Laboratory in Palo Alto. Shockley was both a scientist and an entrepreneur. He developed new scientific ideas. He also tried to make money from them by using them in products his company could make and sell.

Shockley's engineers used germanium to make transistors. Germanium is a chemical element similar to tin. In 1957, several engineers left Shockley's company. They formed their own company, Fairchild Semiconductor, in the nearby town of Mountain View. Here they explored uses of silicon. The engineers fit tiny transistors on a silicon chip. Thus was born the integrated circuit. The integrated circuit is one of the most important inventions in modern history. Like the transistor, the integrated circuit manages small electrical currents. However, the integrated circuit is much smaller than the transistor. It requires much less energy to operate. In the following years, engineers made smaller and smaller integrated circuits on chips of silicon. They called the tiny devices microchips. Microchips allow us to carry thousands of songs around in our pockets.


Microchip

The Entrepreneurs

Among the founders of Fairchild Semiconductor were Gordon Moore and Bob Noyce. Both Moore and Noyce were scientists: Noyce was one of the inventors of the integrated circuit. In 1968 they became entrepreneurs. That is when they left Fairchild to form Intel Corporation. Noyce typed up a one-page proposal and submitted it to Art Rock, a venture capitalist in San Francisco. Rock raised \$2.5 million to fund their new company. The following year, a Japanese company contracted with Intel to design 12 chips for a new calculator. Each chip would perform a separate task, such as keyboard function, display control, and printer command. Intel did not have enough engineers to design all 12 chips at once. But they had ingenuity. Engineer Ted Hoff and his team came up with the idea of using silicon semiconductor technology to combine the functions of all 12 chips onto a single chip. This microchip was ⅛-inch wide and 1⁄16-inch long (.32 cm x .16 cm), yet it contained 2,300 transistors.

The Revolution

Building on this success, in 1971 Intel introduced one of the world's first microprocessors. A microprocessor is a microchip that includes all the components necessary to run a device like a calculator, a computer, or a printer. The Intel 4004 microprocessor had as much power as existing computers that filled large rooms. It could make

Personal computer components

60,000 calculations per second. Microprocessors today contain 5.5 million transistors. They can make hundreds of millions of calculations each second. The modern computer based on the microprocessor is the most sophisticated piece of machinery humans have ever produced. In the 1990s a student working on at a personal computer could gain access to the World Wide Web.

Shockley Semiconductor Laboratory, Fairchild Semiconductor, and Intel are just three of hundreds of companies that grew up in Silicon Valley during the past 50 years. Stanford University provided a steady supply of talented engineers to work in the companies. Scientists and entrepreneurs from all over the country moved to the area. They wanted to work with other people who were transforming the world by creating new electronic devices. The U.S. Department of Defense, as well as the National Science Foundation, invested in such ingenuity and productivity.

The Aftermath

As the Industrial Revolution showed, however, nothing comes free. Nineteenth-century inventions had significant influence on the local environment. So too did the computer revolution. Santa Clara County was once an agricultural region. With the development of Silicon Valley, it has become a manufacturing region. Cement and fabrication plants have replaced orchards. Suburban neighborhoods have sprung up to house people for the growing labor force. Massive highways, built on once-open land, now connect people from the suburbs to their places of work.

Thus, even though the microchip is small, its influence on natural and human systems is large. In California, this has led to the State establishing an "e-waste" program to encourage the recycling of all electronic waste. People have benefited greatly from the computer revolution. Yet these benefits also have resulted in new challenges.

At the beginning of the 17th century, the population of England was approximately 4.5 million. At least 85% of the people made their living off the land. Farming practices continued as they had for centuries. Manual labor and hand tools got the work done. Landholders and tenants grew grain crops and raised cattle, sheep, or pigs. They typically used a three-field system, planting two fields and letting one field lie fallow. Farmers held their property in long, unfenced strips that bordered others' strips. Having open fields meant that they all had to follow the decisions about cultivation that their local parish or village made. Domestic animals grazed in the commonly held fallow fields.

Peasants To Market, Peter Paul Rubens, 1618

The families of most small farmers also worked part-time in a handicraft or "cottage" industry. Many spun and dyed wool and made textiles. Another common industry was iron making. Raw materials like wool and iron were available across the country, as were sources of mechanical power. England's abundant streams turned waterwheels for iron works and milling. Wood charcoal commonly fueled iron-making and glass-making and also heated homes.

Spinning Wheel, Abraham De Pape, 1658

Rural families bought and sold their goods in regional markets, which occurred in about 800 provincial towns. Local farmers dealt with intermediaries who had access to the London markets. In the city, there was high demand for food and clothing. A well-connected road system centered on London, and people increasingly used rivers for transportation. Trade within England and overseas centered on England's seaports. Most trade rested on the export of a few staple products, especially cloth.

Over the course of the 1600s, England's population grew about 27%. As the population increased, the woodlands diminished, because people used wood for fuel and bark for tanning leather. They also used timber to build houses and ships. As wood supplies declined, people began mining coal to use for fuel instead of wood. Coal was burned to provide fuel for metalworking, making salt, boiling soap, refining sugar, making glass, and dyeing cloth. Coal heated houses, and fireplaces and chimneys were redesigned to accommodate the new fuel. In addition, people began building their houses of stone instead of wood.

At the beginning of the 18th century, farming remained the primary livelihood in England. As many as 75% of the people still lived in rural areas. Between 1700 and 1800, the population of England increased by an average of 57%.

Reapers, George Stubbs, 1785

The growing population forced some changes in land use. People drained marshlands to plant crops. Farmers tried new practices so they could grow more on their land. One practice involved planting turnips and other field crops in a rotation system, instead of letting the land lie fallow. Other practices included using newly invented tools, such as a horse-drawn hoe and a seed-planting drill.

The most significant change in land use involved enclosing fields. Landowners regained control of the strips of land that peasants had leased, cultivated, and passed through families for generations. Small farmers lost access to wood and water, while wealthier farmers consolidated and enclosed the better plots of land.

During this time, England's overseas trade expanded greatly. England imported numerous goods from its many colonies in the West Indies, Africa, and North America, and then re-exported them. Woolen clothing did not figure in trades with warm regions, so the textile industry began to change. They increasingly used imported cotton to make cloth. The process began when a supplier purchased raw cotton and brought it to households. In their homes, workers cleaned and spun the cotton into yarn or thread. The supplier then took the spun cotton to another household, where different workers, for a price, wove it into cloth. The supplier delivered the finished textiles to merchants, who took them to the marketplace to sell. The suppliers were the entrepreneurs who began the process of industrialization.

A First Rate Shortening Sail, Samuel Scott, 1736

During the 19th century, England's overseas trade and shipping made it the most prosperous mercantile nation in the world. The English dug deep-water dock basins at seaports and built gigantic warehouses. Shipyards suffered from chronic shortages of manual labor and materials. Most of the country within 20 miles (32.2 km) of a seaport had been stripped of timber to build ships. England began importing timber from northern Europe and hardwoods from the tropics.

The country's exports reflected its growing industrialization. Textiles and iron were most significant. When textile manufacturing was a cottage industry, it employed more workers than any other industry. Water-powered mills that drove machines for spinning and weaving replaced the labor of farming families. This development fostered the birth of the cotton factory. By 1800, steam-powered engines had increased productivity so much that England declared that its goal was to supply spun, dyed, and woven cotton to two-thirds of the world!

The iron industry also grew tremendously. In the past, owners of iron works had to build their iron furnaces in wooded spots where charcoal was available to supply power. With steam engines powering the iron works, iron factories could be located anywhere. To keep up with the increased production, some companies built hundreds of houses for ironworkers.

The Hay Wain, John Constable, 1821

The Cornfield, John Constable, 1826

By 1800, many peasant farmers who had lost their land when farms were enclosed had moved to towns and cities. Coastal towns and the centers of mining and manufacturing industries grew most quickly. One in ten English persons lived in London. In the Census of 1801, the population of London was just under one million. By 1851, it had grown to 2.4 million people.

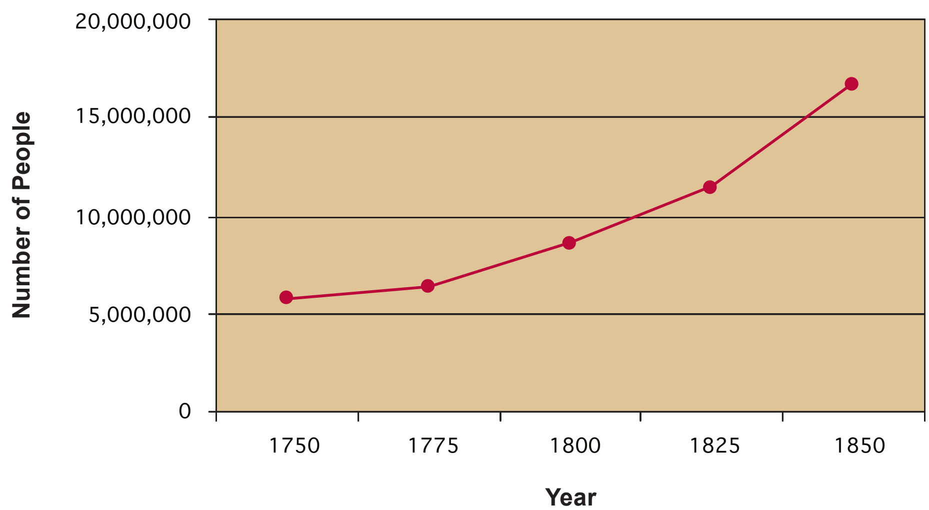
Before the invention of the steam locomotive, horses were the major source of power for transportation in England. Horses pulled wagons, vans, and coaches. They also pulled boats along the newly built canals. These canals made it possible to move heavy goods, such as grains, fertilizers, bricks, and coal cheaply. But by 1850, railways competed with canals, stimulating the growth of both passenger and carrier services.

By the early 1800s, the Industrial Revolution was well underway. The steam engine was the single most important technology of the era. It made possible the machinery that produced vast amounts of goods, and the railroads to move those goods. It also led to major changes in people's lives, as more and more people moved from the countryside to the cities to find work.

Population Growth in England During the Industrial Revolution

London was the largest city in the Western world. In 1800, the population of the city was over one million. By 1850, the population was 2,362,000—more than double the size in 1830. Fifteen percent of England's population lived in the city of London by 1851.

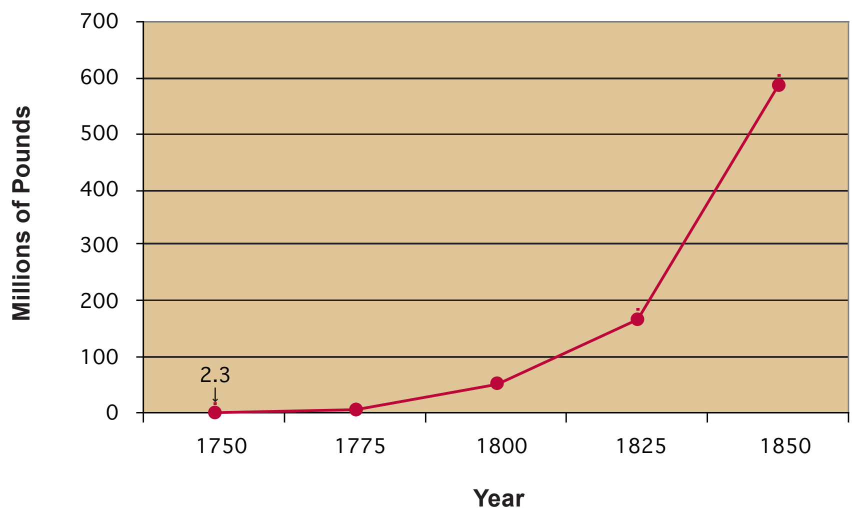
England's Population



Cotton Used for Textile Production During the Industrial Revolution

The textile (cloth-making) industry was one of the first to industrialize. Factory owners imported cotton, made it into fabric, and exported it. Exports brought in a lot of money that manufacturers could reinvest to expand their companies.

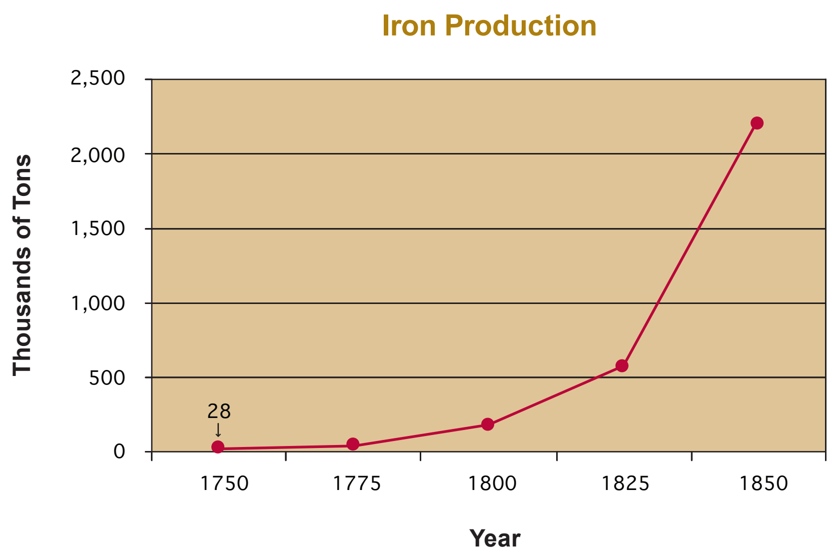
Cotton Use



Source (top): E.A. Wrigley and R.S. Schofield, The Population History of England, *1541–1871 (London: Edward Arnold Ltd., 1981)*
Source (bottom): Charles More, Understanding the Industrial Revolution *(London: Routledge, 2000)*

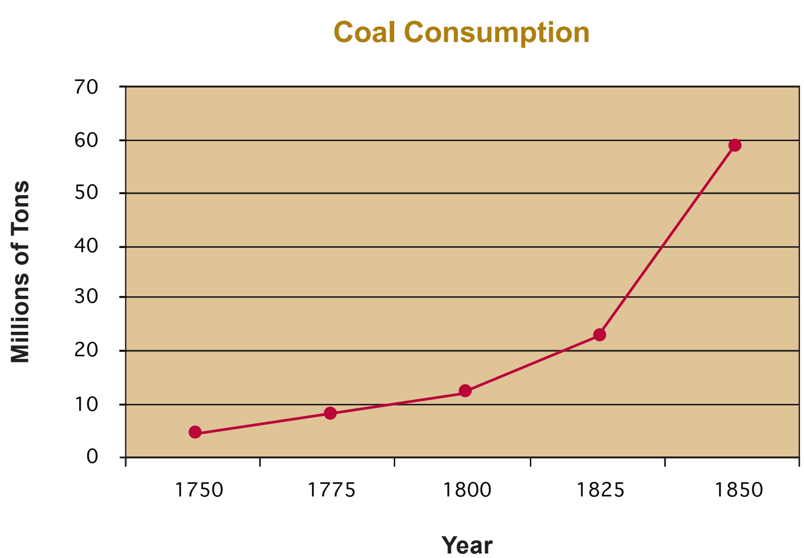
Iron Production During the Industrial Revolution

The iron industry also surged during the Industrial Revolution. Iron is a metal that can be melted and formed into shapes. Among the items made of iron were the machines used in factories, including the steam engines that ran the other machines. Iron was also the primary building material in trains, railroad tracks, and steamships.



Coal Consumption During the Industrial Revolution

Burning coal produced steam that ran steam engines. The steam engine was one of the most significant advances during the Industrial Revolution. With steam-powered machines, production of goods could increase greatly. Some people also started burning coal to heat their homes.



Source (top): Charles More, Understanding the Industrial Revolution *(London: Routledge, 2000)*
Source (bottom): Peter J.G. Pearson, The Energy Journal, *October 1, 1998*

The English Industrial Revolution

By Richard G. Wilkinson

Ecological roots of the English industrial revolution are not difficult to find. The changes started because of natural resource shortages and other ecological effects of an expanding economic system. The economic system was expanding because the population was expanding within a limited area of land. As the traditional sources of energy (like wood) became scarce, people found new sources of energy to replace them (like coal).

The ecological situation that led to the Industrial Revolution was a shortage of land in England. In the centuries before industrialization, the English population depended on the land for almost all their material goods. They grew food on the land. Clothing came from the wool of sheep that ate grass that grew on the land. Transportation depended on horses that also ate food that grew on the land. Large areas of land were needed for forests to grow wood that was used for many purposes. Wood provided almost all the fuel for fires. People used wood to make houses, ships, and farming tools. Even lighting used candles made from tallow (animal fat), required land to produce. As the population increased, there was not enough land to produce all the material goods that people needed.

There already were signs of the growing scarcity of agricultural land during the population rise in the 1500s and 1600s. This was two centuries before the Industrial Revolution began. Disputes over land use had become increasingly frequent. The growth of towns, trade, and industry were further signs that land was becoming scarce. As the population increased, there was not enough land for everyone

Table 1: Index of English Prices.*

Date	General Prices	Firewood Prices
1501–1510	95	100
1511–1520	101	106
1521–1530	113	97
1531–1540	118	106
1541–1550	151	180
1551–1560	215	265
1561–1570	233	332
1571–1582	257	327
1583–1593	297	416
1593–1602	367	451
1603–1612	389	567
1613–1622	398	708
1623–1632	437	1049
1633–1642	451	1208
1643–1652	513	759
1653–1662	477	1026
1663–1672	502	894
1673–1682	539	1052
1683–1692	494	1058
1693–1702	525	1058

* The numbers in this table are not actual prices. Instead, the numbers show relative prices over a long period. The "100" figure for firewood prices from 1501–1510 means that the amount of money that a certain amount of firewood cost at that time was assigned a value of 100. The "106" figure for 1511–1520 means that the same amount of firewood cost 6% more during that period. The figure "95" for general prices in the period 1501–1510 means that a certain set of goods (defined by the historians who compiled the table) cost 95% as much as the sample of firewood chosen for that period. The remaining prices in the "General Prices" column show how much the same set of goods cost during the later periods relative to the amount it cost in 1501–1510.

in the countryside to continue providing for their own needs. A subsistence economy did not work for everyone when land was in short supply. Some people moved to towns and cities to find other work.

People needed to find substitutes for the resources they were getting from the land. The most important substitute they found was to use coal for fires instead of wood. As Table 1 shows, the price of firewood was 10 times higher in 1700 than it was in 1500. Other prices only increased about five times during that period. Writing in 1631, an Englishman named Edmund Howes described how the increasing cost of wood led English people to start using coal instead:

Within man's memory, it was held impossible to have any want of wood in England. But… such hath been the great expence of timber for navigation, with infinite increase of building houses, with great expence of wood to make household furniture, casks, and other vessels not to be numbered, and of carts, wagons and coaches, besides the extreme waste of wood in making iron, burning of bricks and tiles, that at this present, through the great consuming of wood as aforesaid, and the neglect of planting of woods, there is so great a scarcity of wood throughout the whole kingdom that not only the City of London, all haven-towns and in very many parts within the land, the inhabitants in general are constrained to make their fires of ***sea-coal*** *or* ***pit-coal****, even in the chambers of honourable personages, and through necessity which is the mother of all arts, they have late years devised the making of iron, the making of all sorts of glass and burning of bricks with sea-coal or pit-coal.*

Source: Howes, Edmond, ed., Stow's "Annals." London: 1631, cited in Armytage,W.H.G. "A Social History of Engineering." London: 1961.

For many purposes, it was easy to substitute coal for wood. Where this was true, the changeover happened quite quickly, either during the price rise or soon afterwards. Smiths (metal workers) and lime-burners had used coal from very early on. By the mid-1600s, salt boiling, dyeing, brewing, soap boiling, and candle making all relied on coal. However, in processes, such as metal smelting, where the fuel was in contact with the raw material, the use of coal could change the chemical process. Some drying processes involved hanging things in the fumes above the fire. In these processes, coal smoke could create problems that wood smoke did

Coal mine

Extracting bituminous coal

not. Bakers had to change the design of their ovens to avoid contaminating their bread with the fumes from the coal.

As the demand for coal increased and production expanded to meet it, the mining industry soon used up **opencast coal deposits**. Mining companies had to sink mines deeper and deeper. Before the end of the 1600s, depths of up 200 feet were common in all coal fields and some reached nearer 400 feet. The invention of the steam engine was a direct result of the problems posed by deep mines. Deep mines tended to fill up with water, and the invention of the steam engine enabled miners to pump the water up out of the coal mines.

It was not until the late 1700s, when the new cotton mills began to add to the demand for rotary power, that Boulton and Watt made the first steam engine that harnessed steam to produce a rotary motion. Rotary steam power appeared as late as it did not because of the difficulties of invention; rather, no one needed that form of power earlier.

This is a condensed version of a chapter titled "The English Industrial Revolution" by Richard G. Wilkinson. The chapter appears in a book edited by Donald Worster. The title of the book is The Ends of the Earth: Perspectives on Modern Environmental History *(Cambridge: Cambridge University Press, 1988), pp. 80–99. The glossary defines the terms in bold.*

Types of Coal

Opencast coal deposits: Coal lying near the top of the ground that can be removed easily. Opencast coal may also be or in the open side of a hill.

Pit-coal: Coal close to the surface that could be reached by digging a pit. Pit-coal does not require digging a narrow mine shaft deep into the ground.

Sea-coal: Coal transported by sea from the coal mines to the places where it was burned.

The statements below provide evidence that supports different reasons for the Industrial Revolution.

Statement 1

"[E]xports had grown from about £7,000,000 at the beginning of the century to £14,500,000 in 1760. During that interval great changes had taken place in the channels of foreign commerce. In 1700 Holland was our great market, taking more than one-third of all our exports, but in 1760 the proportion was reduced to about one-seventh. Portugal, which in 1703 took one-seventh, now took only about one-twelfth. The trade with France was quite insignificant. On the other hand, the Colonies were now our chief markets, and a third of our exports went there. In 1770 America took three-fourths of all the manufactures of Manchester. In 1767 the exports to Jamaica were nearly as great as they had been to all the English plantations together in 1704. The shipping trade had doubled, and the ships themselves were larger. In 1732 ships 750 tons were considered remarkable; in 1770 there were many in Liverpool of 900 tons…"

Source: Arnold Toynbee, Lectures on the Industrial Revolution in England *(London: Longmans, Green, and Co., 1919), socserv2.socsci.mcmaster.ca/~econ/ugcm/3ll3/toynbee/indrev*

Statement 2

"It has been said that in Great Britain there are above a million of horses engaged in various ways in the transport of passengers and goods, and that to support each horse requires as much land as would upon an average support eight men. If this quantity of animal power were displaced by steam-engines, and the means of transport drawn from the bowels of the earth [coal], instead of being raised upon its surface [food for horses], then… as much land would become available for the support of human beings as would suffice for an additional population of eight millions; … The land which now supports horses for transport or turnpike roads would then support men, or produce corn for food, and the horses return to agricultural pursuits."

Source: 1834 "Report of a Select Committee of the House of Commons on Steam Carriages," quoted in Richard G. Wilkinson, "The English Industrial Revolution," in The Ends of the Earth, *edited by Donald Worster (Cambridge: Cambridge University Press, 1988), p. 90.*

Statement 3

*In the late 1780s in Doncaster, England, Edmund Cartwright built a factory that used his power loom to weave cloth. A local newspaper wrote that in the new factory "a child of six or seven years of age would be able to do as much work in one day as could be done by the older method in a week." * Producing more goods with less human labor (or natural resources or capital) is called "increasing productivity." Increasing productivity usually leads to higher profits for entrepreneurs. But it typically means that some workers lose their jobs, since it takes fewer people to make the goods. Loss of jobs led mobs of angry cottage weavers to attack the home of John Kay in 1753 and the home of James Hargreaves in 1768.*

Quoted in W. English, Source: The Textile Industry: An Account of the Early Inventions of Spinning, Weaving, and Knitting *Machines (London: Longmans, 1969), p. 96.*

Statement 4

In 1708 Abraham Darby found a location in Coalbrookdale, England, that he thought would be perfect for the iron-making business he wanted to establish. The site had "… all the necessary raw materials for expansion and development. Timber was available, together with ironstone, clay, sand, limestone and, what is more important, coal… A little stream, suitable for powering the furnace bellows, ran down the valley through the works to join the river Severn, and the latter river provided a useful highway for the dispatch of finished goods." The next year at this site Darby built his first coke furnace.

Source: W.K.V. Gale, Iron and Steel *(London: Longmans, 1969), p. 26.*

Statement 5

James Watt was awarded a patent for his improvements to the steam engine, established a company with the wealthy manufacturer John Bolton, and retired a wealthy man. Many other inventors were awarded patents on their inventions and tried to make money manufacturing them, with varying success. Thomas Newcomen did well with his steam engine, but John Kay and James Hargreaves never managed to make much money with their spinning and weaving inventions. Edmund Cartwright did not make much money selling power looms, but he did well with his own weaving factory. Similarly, Abraham Darby and William Cort succeeded by creating ironworks where they used their own inventions. Steamship builder William Symington and train locomotive builder Richard Trevithick made good livings as inventors and never really tried to go into business manufacturing their inventions.

Statement 6

"Cotton goods became much cheaper, and they were bought and treasured by all classes. In the past only the wealthy could afford the comfort and cleanliness of underwear, which was called 'body linen' because it was made from expensive linen cloth. Now millions of poor people, who had earlier worn nothing underneath their coarse, filthy outer garments, could afford to wear cotton slips and underpants as well as cotton dresses and shirts."

Source: John P. McKay, et. al., A History of World Societies *(Boston: Houghton Mifflin Company, 2000), p. 752.*

Statement 7

Author Diana Muir asks why it is that New England—a relatively modest, resource-poor area—paved the way for industrialization in the United States. She argues that New England proceeded on its merry way until the mid-eighteenth century, when the region locked onto a collision course with disaster as the population outstripped the available supply of land. Faced with a dilemma, New Englanders could have tried to limit their numbers. They could have migrated to more sparsely populated areas, and many did indeed do that. Or they could have accepted a lower standard of living. But with the growth of the free market and the ability to transport commodities from one region to another, some New Englanders seized on yet another option: producing things for which people elsewhere on the globe would be willing to pay good money. Backed into an ecological corner they used their heads. Environmental misfortune, in other words, was the handmaiden of progress.

Source: Review Essay of Diana Muir, Reflections in Bullough's Pond: Economy and Ecosystem in New England. *(Hanover, NH: University Press of New England, 2000), by Ted Steinberg, Massachusetts Historical Review, http://www.historycooperative.org/journals/mhr/3/steinberg.html*

California Education and the Environment Initiative

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